

INCREASED ANTERIOR TIBIAL DISPLACEMENT IS OBSERVED IN ACL DEFICIENT PATIENTS DURING IN VIVO JOINT MOTION

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INTRODUCTION

Joint kinematics during activity are determined by a complex interaction between external loads, dynamic stabilization from muscle forces, and the internal joint loads in passive soft tissues and at contact surfaces. Changes in functional kinematics result in alterations of patterns of dynamic loading of the joint contact surfaces. These alterations in cartilage loading have been postulated as contributors to the degeneration cycle in articular cartilage which leads to osteoarthritis.

Injury of the knee's anterior cruciate ligament (ACL) results in a clinically observable increase in anterior-posterior joint laxity. The aim of this study is to assess the degree to which this injury may alter knee joint kinematics during activity. Specifically, changes in maximum anterior tibial translation during an open chain knee extension exercise are assessed. The methodology used is cine phase contrast (cine-PC) dynamic magnetic resonance imaging, combined with a rigid body model registration technique.

METHODS

Five subjects who had sustained an isolated complete tear of one anterior cruciate ligament, as well as five uninjured control subjects, participated in this study. All subjects read and signed a statement of informed consent which was approved by the

University of Delaware's Human Subject Review Committee.

Subjects performed a repetitive knee flexion/extension exercise while lying supine within the bore of an MRI scanner (GE Signa LX.). The thigh was placed on a ramp to put the hip in a flexed position, and knee extensions were performed against the weight of the shank. The ramp was adjusted to achieve full knee extension when the toe touched the highest point of the imager's bore; this allowed flexion of the knee to approximately 30 degrees, depending on subject size. Subjects voluntarily synchronized their flexion/extension motions to the beat of a metronome set to produce a repetition frequency of 35 cycles per minute. An optical trigger, positioned below the ankle of the subject, was used to synchronize the acquisition of data with the motion. The scan duration was approximately six minutes.

Cine-PC MR is a flow imaging technique, yielding both anatomical and velocity data on the image plane. A sequence of 24 frames of cine-PC data was collected through the motion cycle on a sagittal image plane prescribed to pass through the joint center. At each data frame four images were reconstructed; one was an anatomical cross-section (magnitude image), and the others were encoded with velocity in the three principal directions of the image.

A high resolution static 3D scan was taken of each knee (1.0mm slice thickness, matrix size

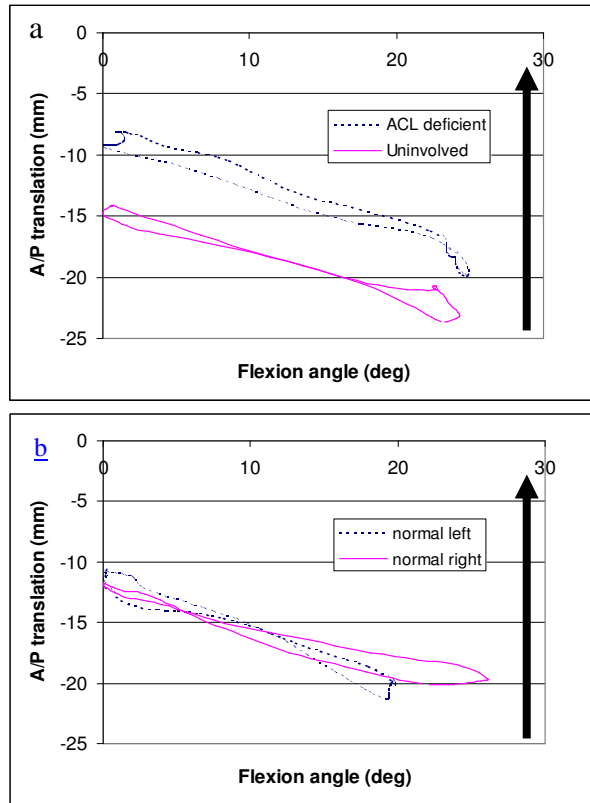


Figure 1: A/P translation parameters versus flexion angle. (a) Sample ACL deficient subject (b) sample control subject.

256x256, field of view=180mmx180mm). The peripheries of the distal femur and proximal tibia and fibula were traced on the images using a digitizing tablet. Custom developed software was used to reconstruct the 3D polygonal graphical models of each bone.

A previously described algorithm (Barrance et al. 2002) was used to develop a modeled trajectory for each 3D model, such that the agreement between simulated cross-section and velocity data most closely matched those observed in the cine-PC MRI dataset.

Anatomically based coordinate systems were fixed within each bone. Landmarks were digitized in the sagittal images in order to establish the directions of the long axes of the femur and tibia in that plane, and the

graphical models were used to determine the other directions. The coordinates of the most distal point in the femoral notch and the tibial eminence were determined in the graphical models. The A/P position of the tibia relative to the femur was calculated as the projection of this vector along the anterior axis of the femur.

RESULTS AND DISCUSSION

Figure 1 shows sample translation parameters versus knee flexion angle, calculated for one of the ACL injured subjects, and one of the uninjured control subjects. The peak anterior translation of the injured knee (-8.1mm) of the injured subject is greater than that of the uninvolved side (-14.1mm), whereas the peak anterior translations are closer to equal side to side (-10.7 vs. -11.8mm). A paired t-test comparison between sides showed a statistically significant increase in peak A/P translation of 6.0mm of the ACL-deficient side relative to the uninvolved side ($p=0.037$.) No significant difference was found in the control group

SUMMARY

An increase in peak anterior translation was observed in the ACL-deficient knees during active joint function. This implies that the ACL is used during these simple flexion-extension movements in unimpaired subjects to reduce anterior translation and that the muscles of the ACL deficient knee do not control the knee so as to eliminate anterior translations.

REFERENCES

Barrance, PJ. et al, *Fourth World Congress of Biomechanics*, August 2002.

ACKNOWLEDGEMENT

Supported by NIH Grant R01AR46386.